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AUTHOR Flohr, John W.; And Others
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ABSTRACT

This study examined the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained while listening to music stimuli. The experimental group comprised 22 children, ages 4 to 6 years old, who received special music instruction twice a week for 25 minutes for 7 weeks. The control group received no music instruction. EEG was recorded during 3 conditions: 2 minutes of sitting quietly with eyes open; 2 minutes of listening to classical music; and 2 minutes assembling puzzles in the Object Assembly subtest of the Wechsler Preschool and Primary Scale of Intelligence--Revised. The children also completed the Spatial Memory Test. Results indicated that the experimental group produced significantly different EEG frequencies than controls, particularly within the frequencies associated with increased cognitive processing and greater relaxation. There were no significant differences between groups on the behavior measures of spatial processing. Results suggest that a clearer understanding of how music and music-related tasks are manifested in the electrical activity of the brain is an initial step in developing better instructional strategies for early education in music. (JPB)

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Children's Electrophysiological Responses to Music

John W. Flohr, Daniel C. Miller, & Diane Persellin

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Abstract

The purpose of the study was to examine the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained while listening to music stimuli. Twenty-two children, aged 4-6, were randomly assigned to experimental and control groups. The experimental group received special music instruction twice a week for twenty five minutes for seven weeks. The control group received no music instruction. The children had EEG recorded during three conditions: 1) two minutes of sitting quietly with their eyes open; 2) two minutes of listening to a Mozart Sonata; and 3) two minutes assembling puzzles in the WPPSI-R Object Assembly subtest. The experimental group produced significantly different EEG frequencies than controls, particularly within the frequencies associated with increased cognitive processing and greater relaxation. There were, however, no significant differences between groups on the behavioral measures of spatial processing.

This paper, *Children's Electrophysiological Responses to Music*, was presented at two complementary international conferences last summer:

Paper presented at the 22nd International Society for Music Education World Conference, Amsterdam, Netherlands, Jul 1996.

Paper presented at the International Society for Music Education Early Childhood Commission Seminar, Winchester,UK, Jul 1996.

Introduction

Since the late 1970's we have witnessed an explosion of technological advances in the field of brain imaging techniques. These advances have taken place in both the neuroanatomical imaging and functional domains. Neuroanatomical brain imaging dates from the invention of the first x-ray. Imaging techniques today have evolved and include computerized tomography (CT) scans and magnetic resonance imaging (MRI's). The resolution of these new brain imaging techniques has given investigators an unparalleled window into the brain's underlying structure.

Functional imaging techniques have the best applicability to the study of music. The functional imaging technique of quantitative EEG or topographic brain mapping was developed in the late 1970's. Topographic brain mapping (TBM) assigns color to brain electrical activity. Different levels of brain activity are reflected by changing colors. These colors can be recorded from the surface of the brain. TBM initially was used to study basic sensory and perceptual phenomena. In the past ten years, researchers have applied these techniques to the evaluation of cognitive processing including music. Recent advances in functional imaging techniques included PET (Positive Emission Tomography) scans and functional MRI's. These techniques are principally used in medical research settings and are invasive techniques. In PET and functional MRI scan studies the subject must ingest or inhale a radioactive isotope; a recording device measures the metabolic activation within the brain.

Isolated research studies in the literature report that specific areas of the brain become activated during the performance of musical activities such as listening to music. Generally, early studies were exploratory in nature and have included only a limited number of adult subjects. With increased accessibility of these imaging techniques in the past few years, however, more researchers are evaluating music and it's relationship to

brain function and structure. Developments in EEG technology have made it possible to assess children's brain activity.

Early brain mapping studies served to distinguish hemispheric functioning during the processing of speech and non speech sounds. By the 1970's, it became evident that the processing of musical sound was much more complex and dependent on individual characteristics. Studies began to focus more on functional brain tasks rather than generalized hemispheric dominance. During this decade the evolution of knowledge and technology allowed for more elementary and detailed research. Bever and Chiarello (1974) examined cerebral dominance in musicians and non-musicians. They hypothesized that the left hemisphere dominates analytic processing and the right hemisphere is active in more holistically or spatially oriented processing. This important study disputed the generalization that speech activity occurred predominantly in the left hemisphere and that the right hemisphere was specialized for many of the nonlinguistic functions. Their hypothesis was supported by other studies conducted by Davidson and Schwartz (1977), Gates and Bradshaw (1977), Johnson (1977), Shannon (1980), and Strong (1992).

The effects of two musical stimuli and silence were measured by monitoring the EEG within the temporal lobes of 30 children (Furman, 1978). The experiment also investigated the effects of music with text (a children's story), music alone, and text alone, on temporal lobe Alpha production. No significant difference was evident between the two aural conditions. Other comparisons revealed no significant difference between age groups in the total number of seconds spent in Alpha, but did find a significant correlation between age group and aural conditions.

Alpha wave production in musicians and non-musicians has also been examined in several studies (McElwain, 1974, Wagner, 1975; Wagner & Menzel, 1977; 1979). Consistent findings in these experiments reveal that musicians characteristically produce overall higher levels of Alpha rhythms than non-musicians. Prior research suggests that

although there is a general tendency for the right hemisphere to process musical sounds, the functional lateralization is ultimately determined by the listener's interest, skills, and relationship to the stimuli. Ross (1992) summarized that the neurology underlying musical and artistic creativity is a very complex affair that involves the whole brain, rather than just the right hemisphere, as popularized in the press. Generally, results of experiments involving musical processing have been shown to be highly dependent on a series of interacting variables such as: the nature of musical material (familiarity, complexity, melodic versus rhythmical versus harmonic), the nature of the task (delayed versus immediate recognition, single versus multiple choice, degree of difficulty) and individual differences (sex, musical skill).

Flohr and Miller (1993) examined the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained during the psychomotor response of tapping to music stimuli. Additionally, electrophysiological differences between two different music conditions were compared. Thirteen children, aged 4-6 years, were selected for the artifact-free nature of their EEG tracings (e.g., little or no extraneous eye or muscle movements). Increase activation was found in the left temporal lobes sites and the right anterior temporal lobe site. The increased activation in the bilateral sensory motor strip probably reflected the motoric output demanded by tapping to the music. The findings were consistent with other research; perception of melody is localized in right mid-temporal areas.

Nine of the thirteen children from the earlier study were given the same task two years later (Flohr & Miller, 1995). Scattered differences were found within the Alpha band between the sum of the amplitudes for the two pre-music conditions "Allegro" (Vivaldi, 1990) and "O'Keefe Slide/Kerry Slide" (Weikart, 1983). Greater Alpha activity was produced for the Vivaldi piece. There were essentially no developmental differences across the frequency bands when comparing the Vivaldi across a two year span. Many significant

developmental differences were found between the Irish folk song from the first and second testing sessions. There was a significant increase in Alpha production in the second testing session. No significant interaction effect was found for the first Vivaldi sum of amplitudes compared to the second Irish folk song sum of the amplitudes. There were many significant differences between the first Irish folk song sum of amplitudes and the second Vivaldi sum of amplitudes. These findings suggested that the developmental differences were strong regardless of the condition and the type of music effects EEG response.

Previous studies have shown that types of music and music training effect brain activity. Barber, McKenzie and Helme (1996) found significant differences in brain activity when subjects listened to baroque and contemporary rock music. Altenmüller, Gruhn and Parlitz (1996) found that training produced better recognition of melody. Verbally trained subjects exhibited increase in activity over the left frontal, temporal, and parietal cortices. Musically trained subjects showed an increase over the right frontal, right frontal-temporal, and bilateral parietal brain areas. Untrained subjects revealed a global decrease in brain activity. Other research suggests listening to Mozart's music effects the brain in special ways (Rauscher, Shaw and Ky, 1993). Rauscher, Shaw, Ky and Wright (1994) have conducted a series of studies on the effects of Mozart music listening on college aged subjects and the effects of music instruction on children. They found that music instruction had an effect on the spatial ability test scores of preschoolers and that Mozart listening had an effect on the spatial ability test scores of college students. Related adult subject research and replications of Rauscher's work have found disparate results (Carstens, Huskins, & Hounshell, 1995; Flohr, Chesky, Persellin, and Flohr, 1995; Parsons, 1996; Stough, Kerkin, Bates, and Mangan, 1994).

Two studies found differences in musically trained adult subjects. Elbert, Junhofer, Scholz, and Schneider (1995) used magnetic source imaging and found that the cortical

representation of the digits of the left hand of string players was larger than that in controls. The finding was correlated with the age at which the person had begun to play. These results suggest that the representation of different parts of the body in the primary somatosensory cortex of humans depends on use and changes to conform to the current needs and experiences of the individual. Schlaug, Jancke, Huang, Staiger, and Steinmetz (1995) examined differences in the corpus callosum between 30 professional musicians and 30 matched controls. Analyses revealed that the anterior half of the corpus callosum was significantly larger in musicians. This difference was due to the larger anterior corpus callosum in the subgroup of musicians who had begun musical training before the age of 7. Recent research with professional musicians links the role of the cerebellum in perception of music (Fox, Sergent, Hodges, & Parsons, 1996). They suggest that there is a circuit involving the right auditory cortex and the left cerebellum that is active for performing music such as Bach but not for repetitive scale drills.

Research is needed to provide baseline data of how music perception is manifested within the brain. The purpose of the present study was to examine the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained while listening to music stimuli. It was predicted that an experimental group would show significant gains on the spatial performance measures as compared to the control group. It was also predicted that an experimental group would show differences in EEG activation during listening to Mozart music and during a spatial ability test, but not during listening to nature sounds.

Method

Participants

Twenty-two children, aged 4-6, who were enrolled in the Child Development Center at Texas Woman's University in north central Texas, participated in this study. The human subjects review committee at the university approved the study. Informed consent

was obtained from the legal guardians of each subject. The sample was selected from a pool of approximately 50 volunteers. The mean age of the participants was 5 years and 3 months. The children in the sample came from a wide range of socioeconomic backgrounds.

Procedures

The children were randomly assigned to either an experimental or control group using a gender-based, stratified random sample procedure. The children were tested at baseline for spatial ability using the Object Assembly subtest from the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R) (The Psychological Corporation, 1989) and a computer based Spatial Memory Test (Miller, 1991).

The experimental group received special music instruction twice a week for twenty-five minutes during a period of seven weeks. The control group received no music instruction for the same period. The music instruction included singing, playing musical games (e.g., "Lucy Locket"), storytelling with music, and listening and moving to Mozart's "Allegro con spirito" (Mozart, 1991). The parents of the experimental group were given a recording of the Mozart sonata and asked to play the music each day at home. At the end of the seven-week period participants in both the experimental and control groups were retested with the WPPSI-R Object Assembly subtest and the Spatial Memory Test. In addition to the behavioral measures, each child had their brain electrical activity recorded during the posttest session.

Instruments

Object Assembly subtest. The Object Assembly subtest from the Wechsler Preschool and Primary Scale of Intelligence-Revised (Wechsler, 1989) was used in this study as a pre and posttest measure. On this task, the child is presented with the pieces of a puzzle arranged in a standardized configuration and instructed to put them together as

quickly as possible. The Object Assembly scaled score (M = 10, SD = 3) was used as a dependent measure.

The split-half reliability coefficients for the Object Assembly Test have a reported range from .57 (5 1/2 year olds) to .70 (4 year olds). The corrected test-retest stability coefficient following a 3-7 week interval was .59 for the Object Assembly Test (Wechsler, 1989).

Spatial Memory Test. The Spatial Memory Test was an original task developed by Miller (1991) to evaluate short-term visual memory in children. The Spatial Memory Test is a research version. The task was developed for the Macintosh® computer using Hypercard™. The task is divided into three sections which increase in difficulty. The entire test includes 60 stimulus cards with a total possible 172 responses. The child is shown a black and white picture of one or more animals on the computer screen for five seconds. The child is then shown a grid and instructed to use the mouse to click in the area(s) where an animal or animals appeared on the previous screen. For example, a child is shown a picture of a camel in the upper right-hand corner of the screen for five seconds, then a grid dividing the screen into four quadrants appears, and the child clicks the mouse in the upper right-hand quadrant where the animal appeared. The task increases in complexity by increasing the number of animals for each stimulus card and the number of grids increases from four to nine over the course of the trials. The child does not receive feedback as to whether the correct location(s) have been chosen. The amount of time it takes to complete each screen and the number of errors is recorded by the computer during the child's performance. A final report tallies all of the results. The depèndent measure used in this study was the number of correct spatial locations recalled by the child.

Brain Mapping Equipment. Brain electrical activity (EEG) was recorded from 19 electrodes sewn into an Electrocap™ (Electrocap International, Inc., Eaton, Ohio). EEG data were collected using the Ceegraph™ Computerized Electroencephalography Kit

(Version 2.63, Model 708: BioLogic Systems Corporation, Mundelein, Illinois, 1992) installed on a 486 PC platform. Linked ears served as the initial common reference for all electrodes and average referencing was later used for data analyses. The ground was Fpz linked with another electrode placed between Fpz and Fz in the Electrocap™. Occular artifact was recorded using two separate leads, one above and one below the right eye of each subject. The EEG was amplified 25,000 times with a bandwidth of .1 to 75 Hz across all EEG channels. Impedances were initially checked using the EEG Impedance Meter (Model 200: GDR Research, Lewisville, Texas). Impedances were kept below 5 Kohms for each electrode. Prior to data collection for each subject, the amplifiers were recalibrated.

A total of eight minutes of EEG data were recorded for each participant during four conditions; eyes open, nature sounds, Mozart listening, and Object Assembly Test. During the eyes open condition, each participant was asked to focus on a fixation point approximately five feet in front of them. During of the nature sounds condition, each participant was asked to listen to a recording of nature sounds (e.g., birds chirping, wind sounds) from Sounds of Nature and the Great Outdoors (n.d.). The nature sounds condition was used as a control for listening to sounds in general as opposed to listening to Mozart in the later condition. In the third condition, each participant listened to Mozart's "Allegro con spirito" from Sonata in D, KV 448. In the final condition, each participant performed the Object Assembly subtest from the WPPSI-R while their EEG was recorded.

Data Reduction and Analyses.

Performance Differences. The Object Assembly scaled score ($M = 10$, $SD = 3$) and the number correct on the Spatial Memory Test were used as dependent measures to test for baseline group differences. The posttest scores for the Object Assembly and Spatial Memory Test were subtracted from the pretest scores to create difference scores. The difference scores served as the dependent variables to test for group differences. An

ANOVA was computed to test the differences between the Object Assembly and Spatial Memory difference scores for each of the two groups (experimental and control).

EEG Differences. For each of the four conditions (eyes open, passive listening to nature sounds, passive listening to Mozart, and performing a portion of the Wechsler Object Assembly test), two minutes of EEG were collected across 19 channels. The EEG data files were edited and initially transformed using the Brain Atlas software (Version 2.52, Model 594: Biologic Systems Corporation, Mundelein, IL.). All EEG files were visually inspected and 30 seconds of artifact-free data were sampled from each file. The channels were monitored for eye movements and excluded from the edited segments as well as any other extraneous artifacts (e.g., electrode pops, muscle artifacts, etc.). Average referencing was used for the edited segments and a Fast Fourier Transformation (FFT) was performed. The FFT separated the EEG into frequency bands (e.g., Theta, Alpha, and Beta).

ASCII files of the FFT files were exported from the CeeGraph Brain Mapping software into the FFT Editing Program (Miller, 1992). The FFT Editing Program extracted the sum of all amplitudes for selected electrode sites for the various frequency bands. The FFT frequencies were broken down into 6 frequency ranges with 3.5 hertz frequencies within each band: Theta (4-7.5 hz.), Alpha (8-11.5 hz.), Beta 1 (12-15.5 hz.), Beta 2 (16-19.5 hz.), Beta 3 (20-23.5 hz.), and Beta 4 (24-27.5 hz.). The electrode sites were limited to the temporal (T3, T4, T5, T6) and parietal (P3, Pz, P4) sites for statistical analyses.

The sum of amplitudes (SAMPS) for the Eyes Open (EO) condition served as a baseline for the remaining experimental conditions (listening to nature sounds, listening to Mozart, and performing the Object Assembly test). The subjects had their eyes open during each of the three experimental conditions. In order to evaluate only the brain electrical activity relevant to the performance of the experimental conditions, the EO SAMPS were subtracted from each of the experimental conditions.

Three 2 Group (experimental and control) X 7 (electrodes) MANOVA's were computed for each of the experimental conditions (nature sounds - EO, Mozart - EO, and Object Assembly - EO). The dependent measures used in the MANOVA's were the sum of amplitudes for Theta, Alpha, and Beta 1, Beta 2, and Beta 3.

Results

Baseline performance differences

The pretest mean scores from the Object Assembly and Spatial Memory measures were not significantly different for the experimental and control groups.

Retest performance differences

Difference scores were calculated between the pretest and posttest Spatial Memory and Object Assembly test scores. A multivariate MANOVA revealed no significant differences between the Spatial Memory and Object Assembly difference scores. Univariate F tests for each of the dependent measures revealed that the Object Assembly difference score was more sensitive to group differences (F (1/15) = 4.23, p = .06) than the Spatial Memory difference score (F (1/15) = 2.36, p = .15). The mean Object Assembly scale score gain for the experimental group was 1.8 scale score points (SD = 1.23) while the control group had a mean gain of .3 scale score points (SD = 1.89).

EEG Differences

Since the small sample size precluded the inclusion of the Condition as an additional factor, a Bonferroni adjustment was made for the separate main effect MANOVA's. By equally dividing the alpha level of .05 across the three experimental conditions, the resulting critical p value for the main effects of each component was set to .017.

EEG Differences during listening to nature sounds. There were no significant main effects for either Group or Electrode site and there was not a significant interaction effect.

EEG differences during listening to Mozart. There was a significant main effect for Group during the Mozart condition (F (6, 93) = 2.73, $p < .017$). The univariate F tests for

the six dependent measures revealed significant differences for the following band widths: Alpha, Beta 3, and Beta 4 (see Table 1). A Roy-Bargman stepdown was calculated to evaluate the relationship between the dependent variables (F (5/93) = 1.30, p = .27). There were no significant differences for the Electrode main effect nor the interaction effect.

EEG differences during the performance of the Object Assembly test. There was not a significant main effect for Group during the performance of the Object Assembly subtest, nor was there a significant interaction between the Group and Electrode site. There was a significant main effect for Electrode site (F (36/411) = 1.96, $p < .001$). The univariate F tests for the six dependent measures revealed significant differences for the following band widths: Theta and Alpha. A Roy-Bargman stepdown was calculated to evaluate the relationship between the dependent variables (F (5/93) = 2.10, p = .07). The means for each of the electrode sites and the post-hoc Tukey comparisons are presented in Table 3.

Discussion

The purpose of this study was to examine the electrophysiological and spatial performance differences between an experimental group exposed to music training and a control group. It was predicted that the experimental group would show differences in EEG activation during listening to Mozart music and during a spatial ability test, but not during listening to nature sounds. As predicted, there were no significant differences between the experimental and control groups within the FFT frequency bands based on the baseline auditory task of listening to nature sounds. When the treatment group was exposed to the Mozart listening condition (a task to which they had already been exposed), they produced greater activation. Significant group differences were found within the Beta 3 and Beta 4 frequency bands (see Table 2). The experimental group produced increases in the Beta 3 frequency band (Mean = .19, SD = 1.74) and in the Beta 4 frequency band (M = .43, SD = 1.81); while the control group produced decreases in Beta 3 frequencies (M = -.81, SD =

2.32) and in the Beta 4 frequency band (M = -.57, SD = 2.20). Beta activation is associated with increase in cognitive processing (Andreassi, 1980). Altenmüller, et al. (1996) reported the similar finding that untrained subjects showed a global decrease in brain activity. The experimental group, who were exposed to the music intervention, showed an increase in cognitive processing during the Mozart listening condition.

There was also a significant difference between the experimental and control groups for Alpha activation during the Mozart listening condition. Compared to the EO condition, the control group produced a mean decrease of -3.09 microvolts across the Alpha frequency band, as compared to a mean decrease of -1.14 microvolts for the experimental group. Alpha is generally associated with a relaxed, resting state (Andreassi, 1980); thus the experimental group maintained a more relaxed state than the control group during the Mozart condition. The experimental group may have been more relaxed during the Mozart condition because of the previous exposure to the music.

It was also predicted that there would be EEG differences between the experimental and control groups during the performance of the Object Assembly subtest, but there were not. There was a possible contamination of how data were collected. All subjects first listened to Mozart prior to performing the Object Assembly subtest. Any beneficial effect of listening to the music was present in all subjects. What was measured was long-term effect of the music intervention in combination with any short-term effects. Future studies will need to control for this by counterbalancing the order of the conditions. There was also a significant electrode site effect for the Object Assembly condition. Theta activation was greatest within the left temporal region of the brain which is consistent with previously reported results (Flohr & Miller, 1993).

It was also predicted that the experimental group would show significant gains on the spatial performance behavioral measures as compared to the control group. The treatment did not significantly affect the behavioral data. It is possible that a longer period

of instruction or enlarging the sample size of the present study would result in a significant effect. The possibility of a significant effect is supported by the probability value of $p = .06$ for the Object Assembly subtest dependent measure. While not significant, the experimental group achieved almost a standard deviation gain after treatment on the Object Assembly subtest, and the control group scaled scores remain relatively constant. One possible problem with using only the Object Assembly test to measure spatial ability is the low test-retest reliability of the subtest ($r = .59$).

One way to understand how to better educate students is to better understand how the brain responds to music. A clearer understanding of how music and music-related tasks are manifested in the electrical activity of the brain is an initial step in developing better instructional strategies for early education in music. The impact of music education on cognitive processes such as spatial visualization tasks remains unclear. While the literature suggests that exposure to Mozart produces enhanced visual-spatial abilities, there are still methodological issues and additional research questions that need to be addressed. The duration and durability of the spatial enhancement and the EEG changes need to be explored. Also, do these experimental changes result from exposure to different types of music other than Mozart? Electrophysiological research in combination with performance outcome based research will help in our understanding of music education. Future music education will benefit from the understanding of how Mozart and other music may effect the functioning of the human mind.

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Table 1

MANOVA for Mozart Condition Differences

	Multivariate	Univariate	
	F	Variable	F
Main Effect			
- Group	2.73*		
		Theta	ns
		Alpha	8.22*
		Beta 1	ns
		Beta 2	ns
		Beta 3	6.32*
		Beta 4	6.52*
- Electrode	ns		
- Group X Electrode	ns		

* $p < .017$, ns = not significant

Table 2

Mozart Listening Group Means for the Alpha, Beta 3 and Beta 4 Frequencies

	Mozart Condition Mean (SD)	Eyes Open Condition Mean (SD)	Eyes Open Mozart Mean (SD)
		Experimental	
Beta 3	8.15 (4.88)	7.96 (4.97)	.19 (1.74)
Beta 4	7.39 (4.73)	6.96 (3.85)	.43 (1.81)
Alpha	17.50 (4.06)	18.63 (3.75)	-1.14 (3.28)
		Controls	
Beta 3	7.22 (2.87)	8.02 (4.01)	-.81 (2.32)
Beta 4	6.34 (2.63)	6.91 (3.55)	-.57 (2.20)
Alpha	16.94 (4.04)	20.03 (4.73)	-3.09 (3.81)

Table 3

Object Assembly Post-hoc Means for the Theta and Alpha Electrode Sites

	Theta	Alpha
	Mean (SD)	Mean (SD)
Left Temporal		
T3	23.64 (5.30)	15.13 (3.11)
T5	24.27 (5.67)	15.49 (2.92)
Right Temporal		
T4	23.03 (3.57)	16.68 (2.89)
T6	21.62 (3.19)	16.62 (2.39)
Parietal		
P3	20.06 (3.58)	13.74 (2.56)
Pz	21.21 (2.22)	16.57 (3.61)
P4	19.69 (3.11)	15.15 (2.59)
Post-hoc Tukey tests	T3 vs P3 ($t = 7.51$, $p \leq .008$)	T3 vs P3 ($t = 3.80$, $p \leq .04$)
	T3 vs Pz ($t = 6.59$, $p \leq .031$)	T3 vs Pz ($t = 4.88$, $p \leq .002$)
	T5 vs P3 ($t = 10.12$, $p \leq .001$)	T4 vs Pz ($t = 4.05$, $p < .02$)
	T5 vs Pz ($t = 9.19$, $p \leq .001$)	T5 vs Pz ($t = 4.12$, $p \leq .02$)
	T5 vs P4 ($t = 6.97$, $p \leq .02$)	